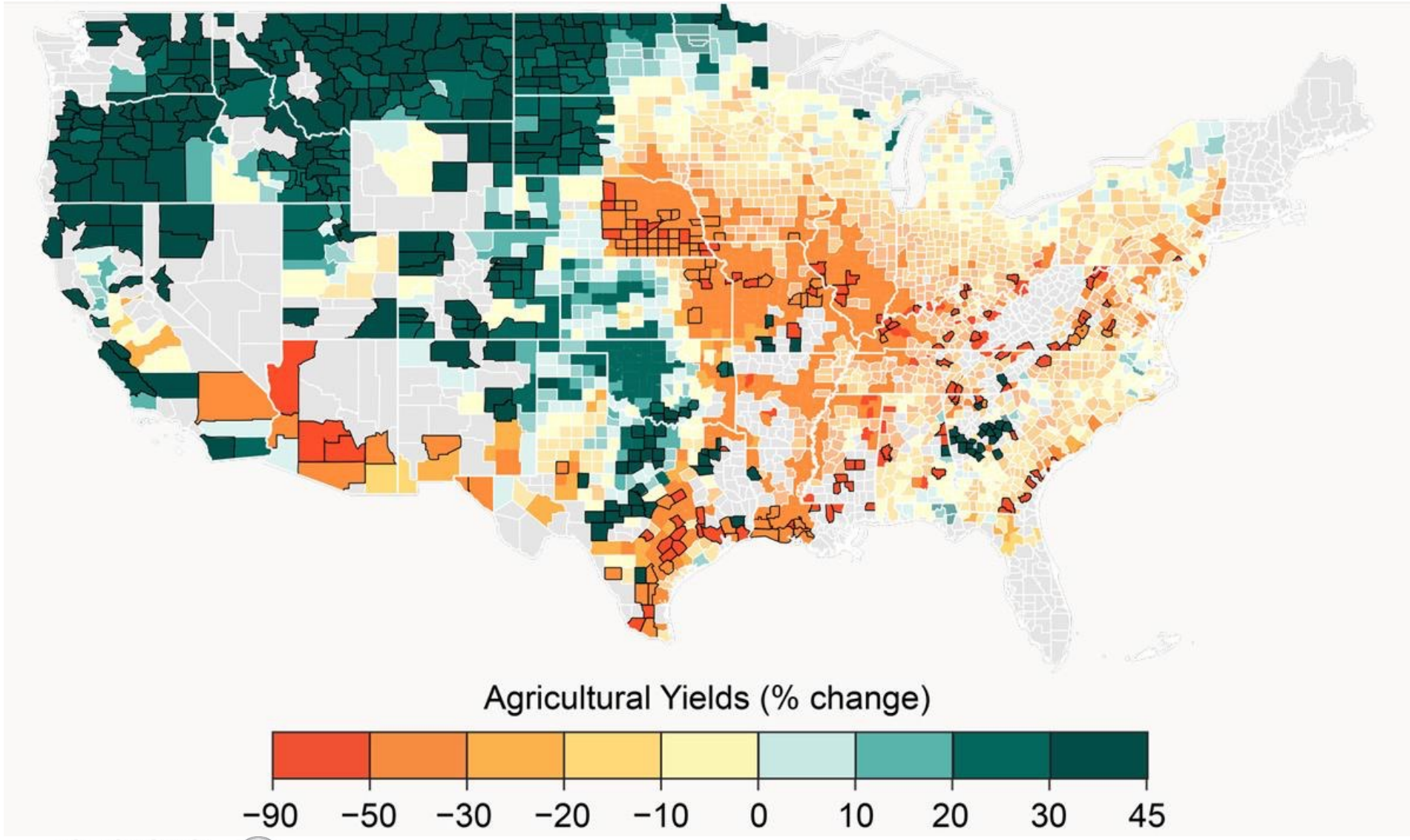
Growing-up: Advanced Technologies to Realize Transformative Industrial-Scale Vertical Farms and Engineered Urban Ecosystems

David Babson, PhD. | ARPA-E Program Director




Climate change = land use change



Fourth National Climate Assessment, Figure 7.6 (Source data: Hsiang et al 2017).

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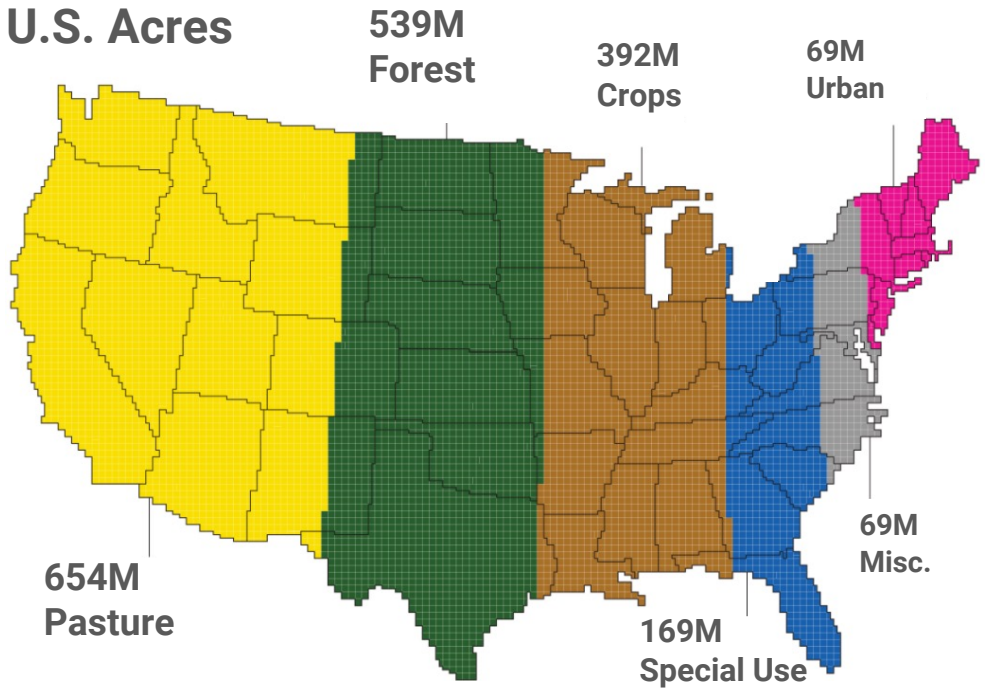
We need to think seriously about how we leverage U.S. lands

An estimated 10^9 ha of new land will be required to feed global population in 2050…

…with new land use demands for energy production, carbon removal, and ecosystem services



Today		2050*
~50Mha, Biofuels ~7Mha, Renewables	➡	+70Mha, E- B+ +250Mha, E+ RE+

*Princeton Net-Zero America
E- B+ = High Biomass
E+ RE+ = High Electrification, 100% Renewable

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Drivers for innovation - And we need to think economy-wide

Carbon / GHG Emissions Reductions

Land Sparing

Our global economy needs to be structured in a way that incentivizes not only land and carbon ‘neutrality’, but promotes becoming both carbon and land negative.

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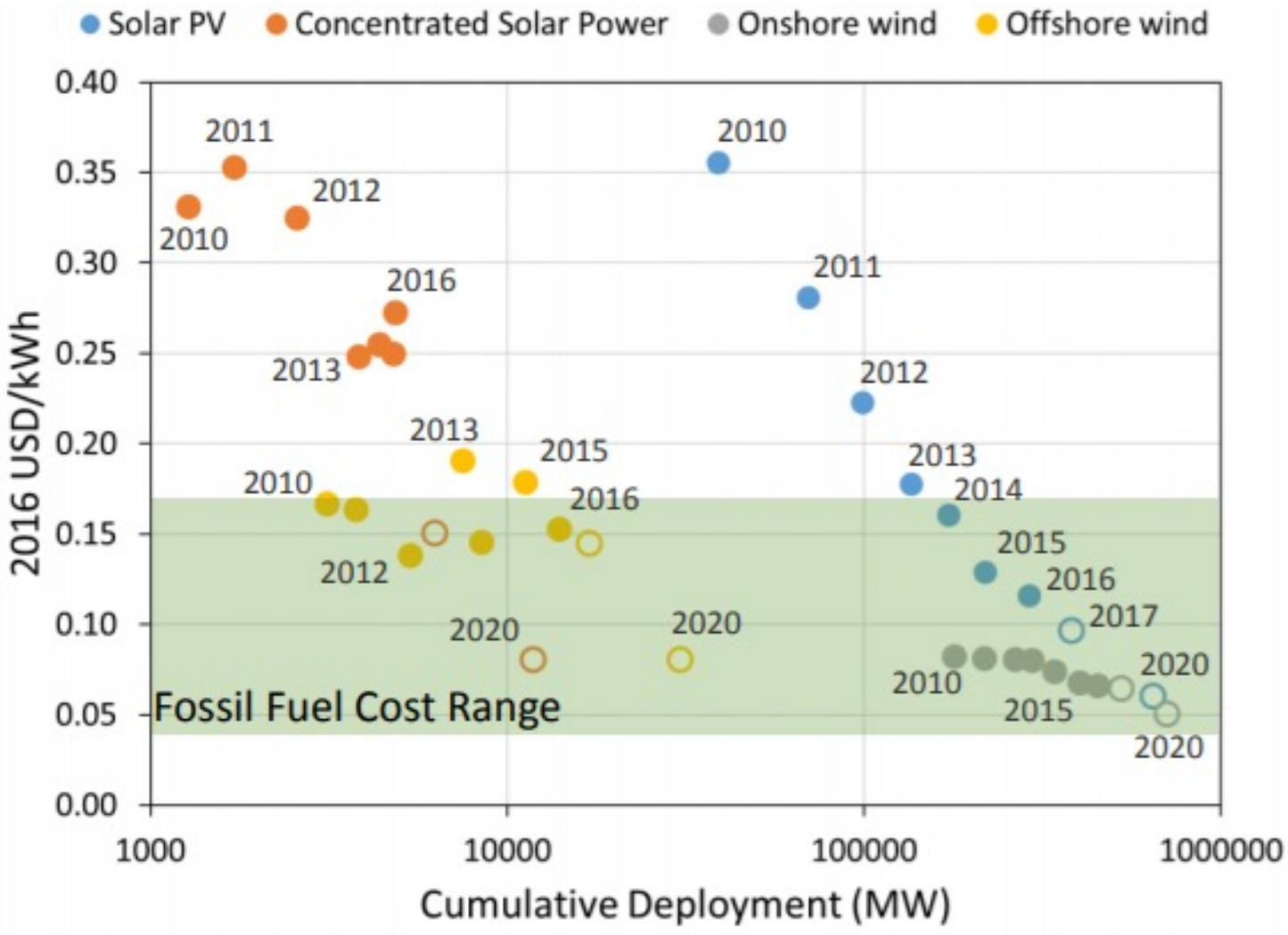
Low-carbon electricity decouples carbon intensity from energy intensity

…and opens new ways of thinking about what we grow, how we grow it, and where we grow it



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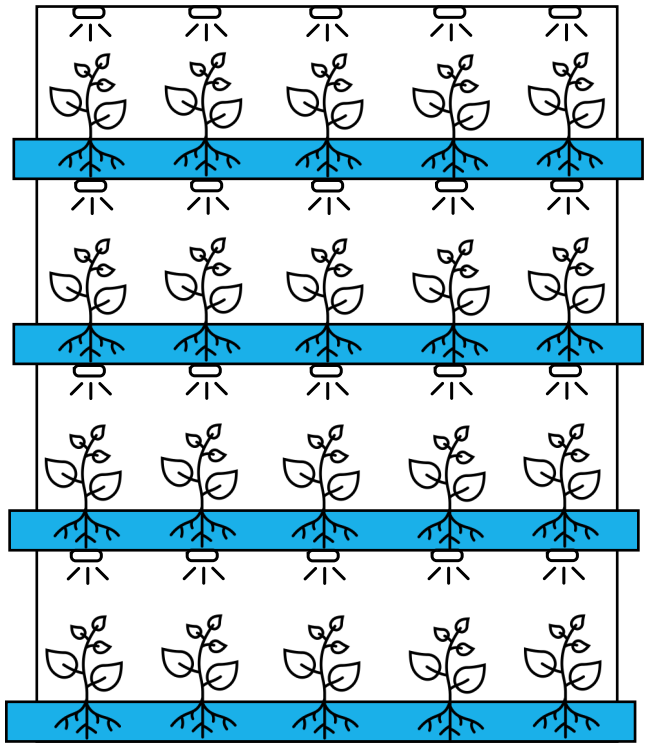
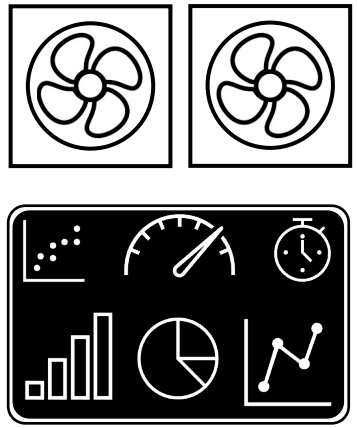
Energy innovations enable new strategies for where and how we farm

Generation:
Low-cost, low-carbon electricity

Building Materials:
Shading, Facades, Insulation

Lighting:
High-efficiency LEDs, Water-Cooled Lighting





HVAC Systems:
Geothermal
Heat Pumps
Ventilation Controls

Chemical Synthesis:
Emissions-Free, Distributed Fertilizer Production

Sensors & Automation:
Precision Temperature & Humidity Controls

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Engler, Nicholas, and Moncef Krarti. "Review of energy efficiency in controlled environment agriculture." Renewable and Sustainable Energy Reviews 141 (2021): 110786.

ARPA-E hard vertical farming challenges

What is being done

What we need to do

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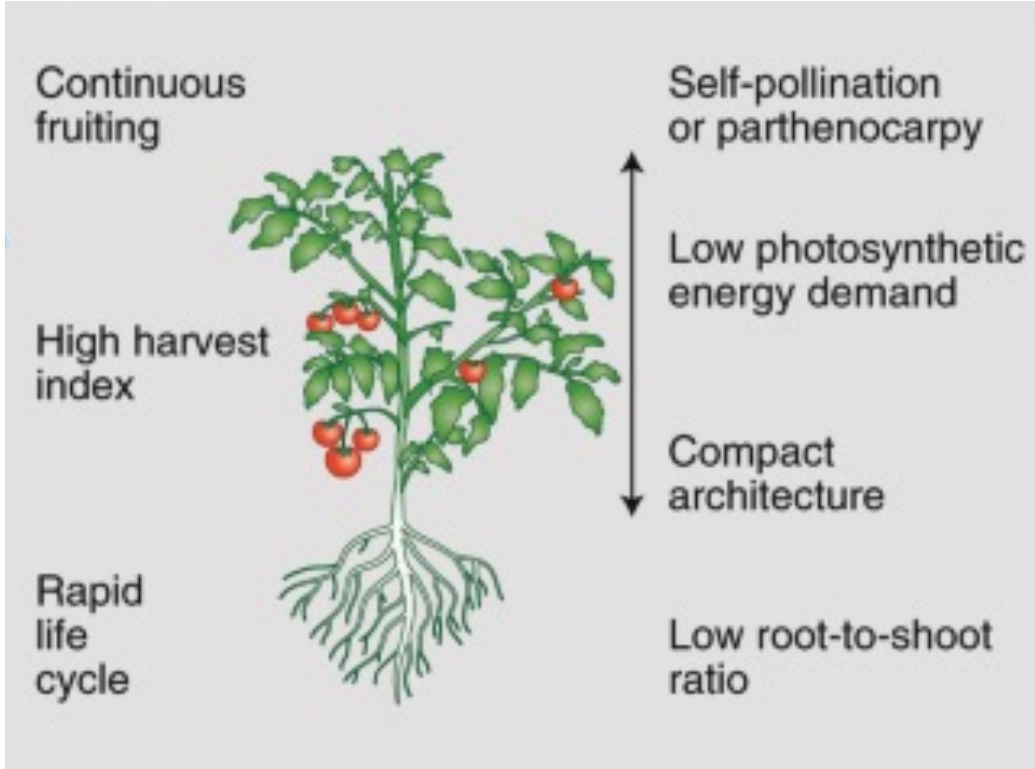
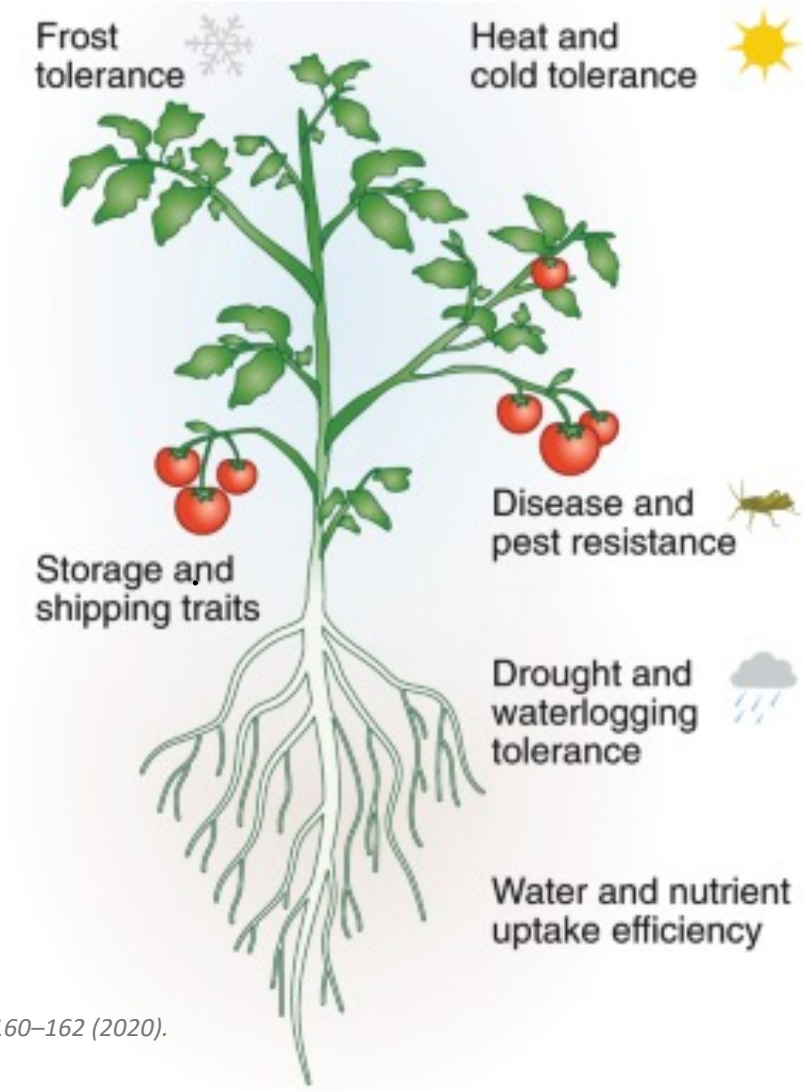
New phenotyping tools allow for innovative crop engineering

Indoor Crops



Outdoor Crops



*O'Sullivan, C.A., McIntyre, C.L., Dry, I.B. et al. Vertical farms bear fruit. Nat Biotechnol **38,** 160–162 (2020). https://doi.org/10.1038/s41587-019-0400-z*

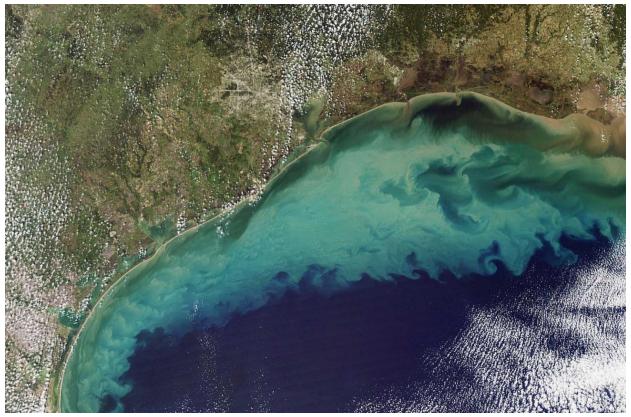
What does “growing up” mean for our environment?

Reduce Inputs

Nitrogen production = 1% global energy demand

70-90% reduction in water use

Eliminate Losses



35% N applied is unrecovered

75% US N_2O emissions

Repurpose Ag Lands

Expand Natural Habitats

Biomass Carbon Removal and Storage

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It’s time to grow up!

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